Science Literacy and Development in the European Union

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Abstract. In March 2000 the Lisbon Agenda set as new strategic goal for the European Union to become "the most competitive and dynamic based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion".

Science and Technology have a major increasing role in today' society and in the lives of everyone of us. No further substantive and sustainable development of our economy and society may be foreseen without a leading enlarged and improved scientific and technological research.

Improving science education throughout the European Union is fundamental as well as effectively setting as major priority to raise the levels of scientific and technological literacy at all levels of our society and in all EU' countries.

The establishment of a science culture in our societies, as steady basis for the improvement of Science and its technological applications, should also constitute a way of promoting a fast full and sound integration of the new country members (and foreseeable future new members) in our enlarged European Union, prosperous and solidary.

Keywords. Science Literacy, Development.

Scientific Literacy and Citizenship

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Abstract. Scientific research has social and moral implications that can no longer be disregarded. Educating students in science involves more than understanding scientific knowledge and carrying out investigations. If students are to grow to become tomorrow's responsible citizens, they need to understand scientific issues as well as their impact on society in economic, social and moral terms. An argument will be put forward in favour of a science education that considers the social implications of scientific activity on both a local and global scale. Science education needs to give more attention to activities placed in contexts and include the social and ethical aspects of the scientific enterprise.

Keywords. Science, Social issues, Ethics, Citizenship.

1. Introduction

This century is characterised by the advancement of media where we can now follow, often live, whatever is happening in any corner of the world from the comfort of our homes. Such commodity, however, also brings with it a new responsibility. If, as active citizens, we are aware of actions and decisions with which we do not agree on social, ethical, and/or moral grounds, we are now responsible to respond and take action. Citizens thus need to be empowered such that they can exert their right to express their opinions. They should be able to use any available channels to try and bring change when they disagree with what is happening in the world around them.

New scientific advancements are also now part of this public knowledge transmitted by media. Scientific research keeps pushing the boundaries. We have experience this in two particularly sensitive areas: cloning and genetically modified organisms (GMOs).

Advances in cloning have moved on from DNA cloning involving the transfer of a DNA fragment from one organism to a self-replicating genetic element, to reproductive cloning where an animal that has the same nuclear DNA as another currently or previously existing animal is generated. There has also been work on therapeutic cloning also called "embryo cloning," involving the production of human embryos for use in research. The goal of this latter process is not to create cloned human beings, but rather to harvest stem cells that can be used to study human development and to treat disease. There have been requests by scientists to governments to allow research in this area. The main area of research is within therapeutic cloning where

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scientists want to study the possibility of using stem cells to clone human organs which can then be used for transplants. This would do away with the problem of finding a matching organ and increase the percentage success for transplants as the probability of rejection would be much less.

Work in biotechnology has led to the production of genetically modified organisms produced by a special set of technologies that alter the genetic makeup of living organisms as animals, plants, or bacteria. Genetically modified products include: medicines and vaccines; foods and food ingredients; feeds; and fibbers. Consequently, farmers have improved the size and quality of their crop. There have been however, concerns on the effect of such products to human health. The effect of cross pollination between genetically modified organisms and natural organisms is as yet unknown as is their impact on the ecosystem. GMOs also bring with them a socio-economic impact – a dominance in the market by industrialized countries, introducing monopolies making developing countries uncompetitive, thus contributing to increasing global inequalities of wealth that already exist.

As more and more journalists report on the advancement in science and the everyday person is informed of developments, the responsibility for scientific research shifts from the scientists to the layperson. It is through science education that the normal citizen can be prepared to tackle and face this new responsibility. Citizens today should feel empowered and consequently should hold opinions about issues. They should also be able to take action if necessary. This can be achieved in different ways in order to influence activities and initiatives being taken locally and globally.

2. Theoretical Framework

What is science for citizenship? Science education across the world has long moved away from the simple transmission and acquisition of scientific knowledge. Students now are also taught and trained the scientific method through laboratory work and investigations. However, process and content do not encompass all that science education is and what it should provide. Many proponents in science [1-4] agree that the public understanding of science involves at least three aspects:

- An understanding of some science content. This refers to scientific facts, laws and theories that make up scientific knowledge and are often found in scientific textbooks;
- An understanding of the scientific approach to enquiry. This does not only involve an understanding of science investigations and the process it involves but also of the role of theoretical and conceptual ideas in interpreting outcomes of investigations;
- An understanding of science as a social enterprise. This includes the human and institutional aspect within which science develops. It also involves an understanding that scientific knowledge is socially constructed by the community of scientists [1].

Mary Ratcliffe [5] represents these three aspects as three areas with their specific aspects but which also overlap to provide a holistic scientific education. She describes the three main components of science to include: scientific concepts (content); practical processes, observational, experimental skills (process); and values and beliefs, cultural and historical contexts, social and environmental issues (attitudes). These are separate but overlap. The intersection of the three components provides students with a view of the nature of science. Science education has tended for a long time to focus on content. The process of doing science has only found its way in the curriculum in these last few decades. Alas, the third aspect, focusing on values and beliefs, has not as yet received the attention it deserves. Although the concept of Science and society, known as STS curricula [6], have been around for some time, the emphasis was more on linking science to its impact on society as a useful tool rather than on the social and ethical implications of scientific research.

How is science related to citizenship? Isin and Wood [7] state that citizenship can be described both as a set of cultural, symbolic and economic practices as well as a bundle of rights and duties. They argue that it is important to recognize both aspects and that many rights often arise from practices which later earn the status of laws. Schmitt-Enger [8] defines active citizenship as the capacity of citizens to self-organise in a multiplicity of forms for the mobilization of resources and the exercise of powers for the protection of rights to achieve the end of caring and developing common good. It is within this latter statement that citizens may be called to act with respect to scientific research. When governments are called upon to give permission for certain research to take place, the normal citizen has the opportunity to express his/her opinion and to exert pressure in order to influence governmental decisions. Citizens today should thus be empowered such that they can take action about issues. This requires that they possess particular skills and attitudes. It is not possible to expect such skills to develop automatically but they must become part of the compulsory curriculum. Science education can provide a valid contribution as it can be the medium through which youths are enabled and empowered to understand social issues related to scientific activity and research, and to learn about what action they can take and how.

How do citizens use science? Jenkins [9] identifies a number of features in an individual's approach to science: These features include:

- Interest in science that is differentiated by science, social group and gender: Different groups show different levels and inclinations of interest. For example, women tend to be more interested in issues related to medicine. Men, on the other hand, tend to be more interested in the physical sciences. Likewise, people of different ages and with different hobbies and lifestyles may hold interests in different branches of science;
- Interest that is linked to decision-making and action: Individuals may only be interested in science simply because it happens to be related to their personal life. For example, they may become very knowledgeable about some medical problem because a member of the family may suffer from it;
- Understanding that is just adequate for its purpose: Individuals tend to be happy with a level of understanding that serves its purpose, without questioning its validity. This often leads to individuals often holding misconceptions about scientific issues. As long as ideas about particular scientific concepts serve their purpose, they are not questioned or challenged;
- Knowledge that is considered at a same level as other types of knowledge: Social, and psychological types of knowledge are usually considered to be on the same level as scientific knowledge;
- Scientific knowledge that is considered alongside its social and institutional connections: Citizens value scientific knowledge depending on its source. Knowledge issued by well known and established institutions tend to be considered more valid than findings from other institutions with not as high a status;
- Attitudes to considering risks associated with scientific and technological issues: Citizens tend to carry out risk assessments related to scientific issues by considering wider aspects such as social, psychological and contextual factors;
- Informed citizens make more discriminating judgments about science and technology related issues: The more informed citizens are about scientific issues, the better they understand the implications and consequences of science-related issues. They will also be able to make better judgment. However, this does not automatically mean that they would necessarily make more rational decisions.

3. Implications to the Science Curriculum

Science education needs to recognize the need to prepare scientifically literate active citizens. It is for this reason that the social aspect of science needs to become part and parcel of students' science education. If the vision of a Europe with empowered active citizens is to be achieved then a great challenge awaits science educators. Science educators now need to prepare students not only with the necessary basic scientific knowledge, but also with the skills needed to evaluate, analyse and be critical of the scientific work. They also need to develop attitudes towards science and sustainable development (moral, social, economic and ethical) in order to be able to make informed and independent choices with respect to scientifically related issues when they become adults. Science curricula need to be changed such that social

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issues become an integral part of teaching schemes. This demands that science education needs to change and to become 'more value laden than content laden' [10].

So, how do we teach about social and ethical issues in science? This definitely cannot be achieved through adopting the traditional transmission view [11]. The transmission approach considers the learner to be passive, receiving information which she/he stores in his/her brain without necessarily understanding the implications to everyday life and society. If one wants students to develop skills, attitudes and values, a different approach has to be adopted. Teaching needs to be organised in a more context-oriented way. Unfortunately, there is still too much science teaching which tackles many scientific concepts in an abstract de-contextualised way.

Teaching within contexts requires active learners who interact with the context being presented. It is thus necessary to have active learners who would make the issues being discussed their own and who can consequently understand the implications – developing attitudes and values in the process. One learning theory that considers learning as an active process is constructivism. Most of the work done in constructivism looks at how students interact with scientific concepts. There has been little work in how it can be adopted to help students understand and develop values and attitudes. In this paper I intend to look at how constructivist approaches may be adopted to tackle the social aspect of science.

What is constructivism and what are its implications to teaching? A lot has been written about constructivism and many educators have tried to develop different strands. However, there is always one common premise, whatever the approach, the belief that every human being needs to put together thoughts, interpretations and explanations which are personal to him or herself in making sense of his/her experiences and situations. The implication is that one needs to think and reflect in order for learning and understanding to take place. In the current context, it is also important for students to stop and think and construct the possible social and ethical implications that may result as a consequence of advancements in scientific research. Rather than considering the construction of knowledge, there can also be construction of implications, consequences and impact on individuals and society within a social, ethical and moral dimension.

How do students make sense of experiences? Windschitl & Andre [12] argue that students construct their knowledge from individual and/or interpersonal experience and from reasoning about these experiences'. The learning process thus involves active interaction between the learner and the content to be learnt. Duit and Glynn [13] 'view constructive learning of science as a dynamic process of building, organising, and elaborating knowledge of the natural world. Although in this case, reference is made to content, there is also an understanding that learning is an interpretative process involving individual's constructions in meaning making relating to specific situations.

The constructivist theory, whatever the approach, holds that individuals construct for themselves a unique picture of the world, and that in constructing this picture they must understand the concepts which, in the case of science, the scientific community accepts as being true. We are now questioning whether this theory of understanding knowledge can be extended to understanding social aspects. If one were to focus more on the process of meaning making than on the meaning of concepts, then it is possible to consider that learners can construct visualizations of possible situations as a consequence of actions. It is in such situations that one can understand the implications of decisions taken with respect to scientific research. If one accepts that constructivism also allows the meaning process beyond that of content, the question for science teachers then becomes how to help students conceive and understand implications and impacts rather than just concepts. Hence the argument is being put forward is that in favour of adopting the constructivist approach when teaching science for citizenship.

Constructivism has been widely adopted when developing teaching schemes aiming at improving students' understanding in science and specifically in targeting students' wrong ideas, known as alternative frameworks. Examples of the main approaches included conceptual change [14], Driver and Oldham's [15] constructivist approach adopted in the Children Learning in Science (CLISP) project, concept mapping and mental models. Common features which emerge are the use of cognitive conflict, metacognition and the application of

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scaffolding in promoting students' active participation in learning.

Duit and Glynn [13] suggest that a constructivist model of science instruction demands that teachers need to encourage students to think metacognitively (thinking about their own thinking) by activating students' existing mental models. This can be achieved by supporting the process of constructing mental models, helping students to transform conceptual models into physical ones and to think out loud. Teachers need to encourage students to represent a problem in a variety of ways and have students assume the role of learners, employ reading, writing, discussion and debate. They also need to begin lessons with simple concepts and problems to foster motivation and question students 'who, what, when and where', encouraging students to pose their own science problems. These are approaches that fit in well when considering social implications. This approach is discussed in more detail further on.

These aspects emphasise the need for learning to be stimulating. One can achieve this through the use of challenge or cognitive conflict, reflection or what is known as metacognition, and the ability to build patterns [16]. It is important to provide children with opportunities where they can work out their ideas in their own language [17] and to look at the implications of such issues.

What type of constructivist learning activities can teachers adopt to teach about the social aspect of science? Central to any activity that targets teaching about the aspects of science is that students need to have ownership of the issue being considered. It is only through ownership that students can empathise and understand the various implications of scientific issues. In order to give students ownership, it is important that the issues being considered are relevant and of interest to the students. This can be achieved by choosing themes that are close to their lives, or that is a current debate on the media locally or internationally. Teachers often tend to steer away from what are considered 'hot' issues. If one is to be seriously committed to equipping students with the skills to become active citizens, then it is such issues that need to find themselves in the curriculum. It is through tackling the difficult issues that students learn, both through their input but also through the teacher's example about how to develop opinions and how to voice them appropriately in exercising their rights as citizens.

So what type of activities can teachers organise? Attitudes and values that promote social issues related to science can only be dealt with within a holistic approach. Whatever the teaching methodology, there needs to be space for students to research, learn, share opinions and consider ways in which they can take action. It is through such approaches that students can be empowered to become active citizens. Here are some approaches that teachers can adopt.

Discussion:

At a very low level of interaction, teachers can organise a simple discussion of an issue. What is important is for the teacher to give students the space and the confidence that their opinion has the same value as anybody within the class. Children can thus give their views about the implications of the scientific issue without any fear of ridicule or value judgements from the teacher or their peers. Promoting discussion is quite a low level of active engagement. However simple this approach may seem, teachers still need to have specific skills. They need to know how to think up a relevant and debatable situation; how to ask questions that provoke discussion; as well as how to create an atmosphere where students feel that their opinions are valued and provide a valid contribution to the discussion. Teachers have to be careful to remain impartial, act as chairs and steer discussion on the issue without taking over or imposing their position about the issue. In short, the teacher needs to be well prepared in terms of content background to the issue, but also possess the necessary social skills to promote and create a constructive discussion which would help students learn how to reflect, express an opinion as well as be able to build a logical argument which they can back if challenged. Examples of topics which one can choose for discussion may include controversial issues such as 'What if you are exactly like your mother/father?' in considering the implications of cloning, 'Would you want the government to build an incinerator 100m away from your home?' in considering air pollution; 'Would you allow scientists to carry out research on human embryos?' and many others. A common aspect of these examples is that they do not have clear cut answers and thus easily give rise to debate.

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Poster production:

Part of teaching about the social aspect of science involves teaching students how to express their opinions in different but positive ways. Children can be asked to draw posters to send messages about the issues that they have discussed. Posters are usually designed to send out messages to specific groups. Teachers can help students research and decide on the implications of the scientific issue being discussed, and to find ways of expressing their opinion through drawings, catch phrases, statements. In doing such activities, it is important to specify the target audience. There is a difference between a poster prepared for fellow students to one with which one protests in front of the Prime Minister's office. When one changes the audience for which a piece of work is designed, it promotes understanding of different perspectives of an issue to different interest groups;

Language activities:

Most of the activities in schools involve practice in one form of the language, it being talking, listening, reading or written work. Teachers can utilise these language activities to include a particular social issue. Teachers can take the opportunity to include social issues related to science as contexts for language activities. Students can be asked to read texts from newspapers, scientific journals, or any other literature about an issue and asked to consider the implications and write about it, or make an oral presentation. This makes students pay attention to what they have to say and in what way, leading to active reading, writing – knowledge construction and understanding. In fostering understanding of different perspectives, students can be asked to take up various roles, such as the government's position, the activists' view, the local authority etc. It is a way of helping students realise how the same issue impinges on different interest groups in different ways, how different groups may have different agendas and how these can influence the way in which people interpret situations and take standpoints with respect to scientific issues;

Research Projects:

A social issue can be tackled within a research project which would allow the time and space to go in depth into the issue, understand the scientific concepts involved as well as the implications on society from an economic, social and ethical aspect. The research project can focus on a social issue that is of current concern. A newspaper cutting, news report or some other form of contribution in the media can be used to spark off the discussion. However, in this case, students will be asked to look up some scientific information about the issue. It is important to try and elicit differing ideas and opinions so that cognitive conflict would be present. Cognitive conflict is one way of promoting meaningful learning. Getting students to disagree will motivate them to look up information and to formulate arguments in favour of their belief. It is a strong learning tool that makes learning a lasting experience. One particular example within the context of Malta would be that of fish farming – what it is, how is it managed, what are the implications to the marine environment around it, how does it affect the economy in such a small island, will it affect local bathers, will such abundance of food attract big fish towards the island, what is the effect of all the fish excreta beneath the fish farm, are there any adverse effects on human health when people consume artificially grown fish. These are just a few of the issues that students can go into in just one topic. It would require that students learn how to find knowledge, be it through the use of the internet or talking to experts. Students need to learn how to be critical of the information gathered, to understand that different players may have hidden agendas and consequently present a biased picture of the situation, how to size up things for themselves rather than accept all that is said to them. In short, one such project would probably give students much more skills and scientific knowledge than the long hours of de-contextualised knowledge that is usual practice in schools;

Role playing:

Teachers can ask students to go beyond learning and understanding issues. They can ask students to take different roles and act out by simulating situations. Role playing is one way of getting students to understand how people in different positions view things according to their personal or corporate agenda. One may not necessary share the attitudes and beliefs that the different parties may take in such situations, but it will definitely help students to understand the undercurrents and motivations which may at times be behind decisions and actions taken.

Let's consider one example where students are asked to consider the case of cloning and the decision put forward to government to allow research in a particular type of cloning. Students can be asked to represent different groups, for example, the government, the Health Minister, the research institute proposing the study, the anti-cloning lobby, the normal citizens etc. All students will need to understand the same scientific concepts, but each group will have to look at the issue from a different point of view and with a different agenda. They will learn how the same concepts can be used to put forward different arguments which may be in conflict with each other.

There are a number of common features on which all of these types of activities are based. In fact some of such examples have been already written about by Lock and Ratcliffe [18]. The one single significant common factor is that children are actively involved in the learning process. When one deals with values and attitudes it is difficult to transfer these by simply 'telling'. One needs to place children in a position where they can understand the implications and how different groups may have different agendas that may not be the welfare of the population or the world. Understanding such aspects can be achieved through getting students to disagree by holding different points of view.

All the activities listed involve the use of language in some form or other. In the same way as one understands a problem in the process of formulating a question about it, will language, similarly, facilitate the understanding of the intricate issues involved when one considers the environmental and ethical issues related to science and scientific research.

Teachers too often assume that students are able to reflect on the activity that they are doing at school and to appreciate the intention behind such educational actions. However, this is often not the case. Metacognition, one's awareness of one's own thinking process, is essential to empower learners and help them gain conscious control over their own learning processes. Teachers, therefore, need to find time to ask students to reflect on what they have been doing, why, they have been doing it and the value of doing it. They should encourage students to trace how their level of knowledge, opinion, and attitude has changed as a result of the learning activity. Students do not automatically reflect on the activities that they do. Teachers need to promote this reflective process until it becomes internalised.

Obviously, the methods suggested are not exclusive. Whatever the type of activity, what is most important is to get the students involved. However, there is a changing view of what doing science in schools involves. There is a strong argument in favour of introducing the social aspect of science as an integral part of the science curriculum. There are also implications for changes in the way that science curricula are designed and what that they are taught. Many times, science involves the understanding of concepts that are detached from their implications to everyday life and society. Laboratory work is used mainly for the illustration and understanding of these concepts and to train students in the process of doing science. This new approach to science being advocated involves a more holistic view of science where case studies about relevant current scientific issues are considered such that students have the opportunity to appreciate the implications of science to everyday life, society and the environment. Teachers need to change their view of doing science and to adopt different teaching methodologies to those that they have been using up to now.

4. Implications to Practicing Teachers

These new approaches require different teaching capabilities than those for which teachers have been trained during their pre-service training. This demands that teachers be provided with training to equip them with the new sills required to deliver a different approach and curriculum. Teachers need support at different levels: technical; planning; pedagogical and management level. At the technical level, teachers need to become familiar with ICT and have good working knowledge of basic programmes. Proficiency in ICT is crucial as students would be required to carry out most of their research on the internet. In today's knowledge society, it is impossible for teachers to keep abreast of all the content knowledge that is required for teaching, particularly if one is considering new technological advancements that are being conquered every day. Teachers, rather, need to possess the technical capability to use ICT in their teaching to enable them to help their students search and find information about the issues being discussed.

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Teachers require new competences to tackle open-ended activities which lead to more than one possible solution, Teachers may feel insecure as to how to plan and prepare their lessons. One way of overcoming this insecurity is through good planning and preparation. Rather than preparing the one correct possible method leading to one solution, teachers need to learn how to plan resources which would enable students to look up relevant information. Teaches need to know how to deal with the possibility of different outcomes and how to plan processes rather than products. Such skills are not easily acquired as they always bring with them a degree of uncertainty as how lessons would proceed.

Good planning is only possible if teachers have good pedagogical background knowledge. Recent years has seen great research providing contributions and insight about the teaching and learning process, and particularly with respect to how this applies to the learning of science. New modern approaches, mainly within a constructivist framework are being advocated by many researchers. Teaching about the social aspect of science falls within these new trends. Consequently teachers are required to possess new pedagogical skills that they may not possess. It is therefore necessary to help teachers develop, either through in-service training or in-school support, these new and up to date skills such that they will be capable to respond to these new demands in the teaching of science. In addition, there also needs to be a cultural change as to how teachers view learning and how teaching in schools should be. This cultural change is crucial as it is only when teachers are convinced of the efficacy of the approaches that they adopt that they manage to deliver the curriculum effectively.

These new teaching approaches demand that teachers have different management skills than those usually required in the traditional teacher-centred approach. Having students working on projects where different groups of pupils may be at different stages in their work and carrying out different activities concurrently requires particular management skills. It is useless to have good pedagogical planning and delivery but bad management. Teachers can only provide quality experiences if they possess all these capabilities combined. The role of the teacher has evolved in a much more complex way than that conceived a few years ago. As the world becomes more digitized, complex and intertwined, the same can be said to what should be taking place in schools. It is ultimately the schools' responsibility to prepare students for a productive and independent life in the world and they consequently have to mirror the present expectations and demands rather than yesterday's reality. This means that teachers carry a great responsibility in ensuring that tomorrow's citizens would be capable of being truly active citizens that ensure a better future for humankind.

5. Conclusion

We are living in a fast changing world with new knowledge and practices generated every day. The science education provided to students should mirror this change. Rather than aiming to cover all the content generated, it makes more sense to aim to develop independent learners who can understand scientific issues and their implications to everyday life. This calls for a radical change in the way that we view science education. It is essential that this change is brought about, and quick, as otherwise we would end up with a future where citizens will not be able to handle appropriately the scientific processes that our scientists have developed. Such great power in ignorant hands would be dangerous to the future of our world. It is thus essential to act now if we want our future generations to enjoy a better quality of life than we have today.

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The Path to European Integration as a Mechanism for Quality Improvement in Science and Technology Education

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Abstract. If the European Union is currently under-performing in the knowledge-driven economy, in relation to some of its main competitors, this is due partly to an overall level of investment which places inadequate emphasis on education and human resource development. With respect to Science and Technology Education the efforts to develop a set of educational objectives have identified three key issues:

- The importance of Science and Technology Education to the future of European Society; closing the gender gap; raising the level of interest in choosing to study science and in engaging in lifelong learning; broadening the constituency for science, and developing a scientific culture.
- Teaching and Learning in Mathematics, Science and Technology: differentiating the educational objectives in relation to age, relevance and future priorities. Teacher preparation and support. Informal and non-formal learning opportunities. Strengthening, sustaining and spreading good practices. Encouraging a culture of educational innovation with emphasis on improving the quality of learning outcomes.
- Career guidance: enhancing partnerships between schools and Universities and between schools and industry.

In many European countries there are marked changes in the proportion of students choosing to study science related subjects in school at the point where these become optional. At the same time, the educational objectives across Europe, as well as the development strategy outlined in Lisbon, have substantial implications on the changing expectations of society from the European educational systems and increase the projected numbers of required personnel in science related careers. Such trends demonstrate the crucial importance of education in policy